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AUTHOR Jolly, James A.
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ABSTRACT

This paper discusses the conceptual framework and methodology of the technology transfer process and develops a model of the transfer mechanism. This model is then transformed into a predictive model of technology transfer incorporating nine factors that contribute to the movement of knowledge from source to user. Each of these factors is examined in turn. Based on the predictive model, the author constructs an equation for calculating the "linker index," which represents the effectiveness of an organization's ability to achieve technology transfer. The predictive model is then divided into two parts to reflect the relative importance of the formal and informal communications components of the transfer mechanism. (JG)

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THE TECHNOLOGY TRANSFER PROCESS:
CONCEPTS, FRAMEWORK AND METHODOLOGY

James A. Jolly*

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Naval Postgraduate School
Monterey, California 93940

*The author is an Associate Professor in the Operations Research and Administrative Sciences Department of the Naval Postgraduate School, Monterey, California 93940.

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Abstract

The concepts, framework and methodology of the technology transfer process are discussed. On the basis of research a model of the transfer mechanism is developed. This model is carried through several iterations to arrive at a predictive model of technology transfer. The model is useful in terms of exposing difficiencies in the acceptance of new and/or innovative technology. In addition the model has a future usefulness in terms of providing a basis for a quantitative measure of the effectiveness of an organization to capitalize on the technology transfer process.

Introduction

"Research and development is neither a substitution for production nor a method of procurement; it is rather a search or process of discovery. Money spent on R & D is not directly intended to buy missiles or airplanes; it buys knowledge," (Klein, 1958, pp. 1-2).

As expenditures for research and development have continued to increase, the existence of what Havelock terms "the knowledge gap" has become readily apparent to both the suppliers of sources of technological information and the potential users of the knowledge (1971, pp. 7-1). Specifically, the Naval Facilities Engineering Command was cognizant of such a knowledge gap and was concerned with attempting to define a technology transfer mechanism which could effectively alleviate the effects of the knowledge gap when implemented.¹

Concepts of Technology Transfer

"Federal agencies have tended to interpret their technology transfer mission in terms of documentation and formal information dissemination," (Doctors, 1969, p. 12). Federal agencies embarked upon this interpretation because it was formerly thought that dissemination of technical literature was an efficient mechanism for accomplishing the task of technology transfer. Not until

¹This research was supported in part by the Naval Facilities Engineering Command, Washington, D.C. The reports to NAVFACENG Command are NPS-55CF 72061A dated 30 June 1972, and NPS-55Jo 74061 dated 30 June 1974. The principal researchers on the project were, J. W. Creighton, J. A. Jolly, and S. A. Denning.

recently has the orientation of technology transfer shifted to the realization that the transfer of technologies is one aspect in the larger process of technological innovation. Technological innovation is broadly defined to include an idea which is perceived by the individual to be a new method, means, or capacity to perform a particular activity. The result of technology transfer may thus be the acceptance by a user of a practice common elsewhere, or may be a different application of a given technique designed originally for another use (Gruber and Marquis, 1969, pp. 255-256).

Consequently technology transfer has been redefined as "a purposive, conscious effort to move technical devices, materials, methods, and/or information from the point of discovery or development to new users," (Gilmore, 1969, p. 2). As a planned and rational movement of technology (Spencer, 1970, p. 27), it must be distinguished from the more general process of technological diffusions which is the historic unplanned movement of technical or social items from one user to another without any focused effort to actively transfer the particular item. This new concept of a technology transfer program has merely been broadened to include both dissemination of scientific knowledge and concern for actively expediting the transformation of knowledge into meaningful innovations.

The impression that technical data dissemination and technology transfer are the same has created the misconception that the end product of the research and development process --

knowledge -- is in final form when properly documented and disseminated. To record, catalog, and inventory the knowledge is a necessity; but it is not the final step if the knowledge is to be utilized in the sense of being the main or contributing factor leading to a meaningful innovation.

McDonough (1963, Ch. IV) argues that information has a value (at least subjectively) and will be sought only to the extent that its value exceeds the cost of obtaining it. The scientist or engineer is perceptibly able to value the information only if he is aware of its existence: Otherwise the value is zero and the information will not be sought.

Theoretical Models of Technology Transfer

Since there is a perpetual queue of information waiting to be assimilated outside of a receiver's mind, we are confronted with the task of defining a transfer mechanism which recognizes the limitations of, and the necessity for, technical data dissemination. In simplified terms, a program of technology transfer must include a mechanism which effectively links or couples the source of knowledge with the eventual utilization of that knowledge (see Figure 1).

The transfer mechanism is not merely a series of communication channels through which information flows. As a complex mechanism involving personal interactions it is not necessarily "additional persons or groups interposed between the two systems,"

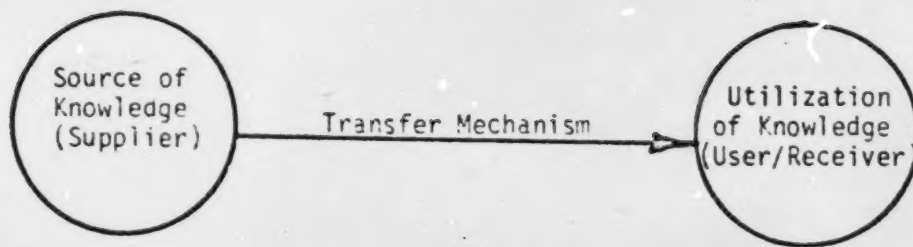


Figure 1 A Simplified View of the Transfer Mechanism

The transfer mechanism represents the interaction of people and need not be independent, but may be incorporated in either the supplier or user environment.

(Havelock, 1971, pp. 7-11). It is a human resource mechanism which can be incorporated into either the supplier or the user environment even though the consensus is "that action for really effective technology transfer should start with potential users rather than sources," (Gilmore, 1969, p. 3).

The concept of a transfer mechanism is delineated in the following conceptualization of the process of technology transfer shown in Figure 2. The model was developed essentially independent of the literature. As the literature search progressed it seemed that there was a great deal of commonality between the formulated model and similar models in the literature. This discovery served as a validity test of early hypotheses.

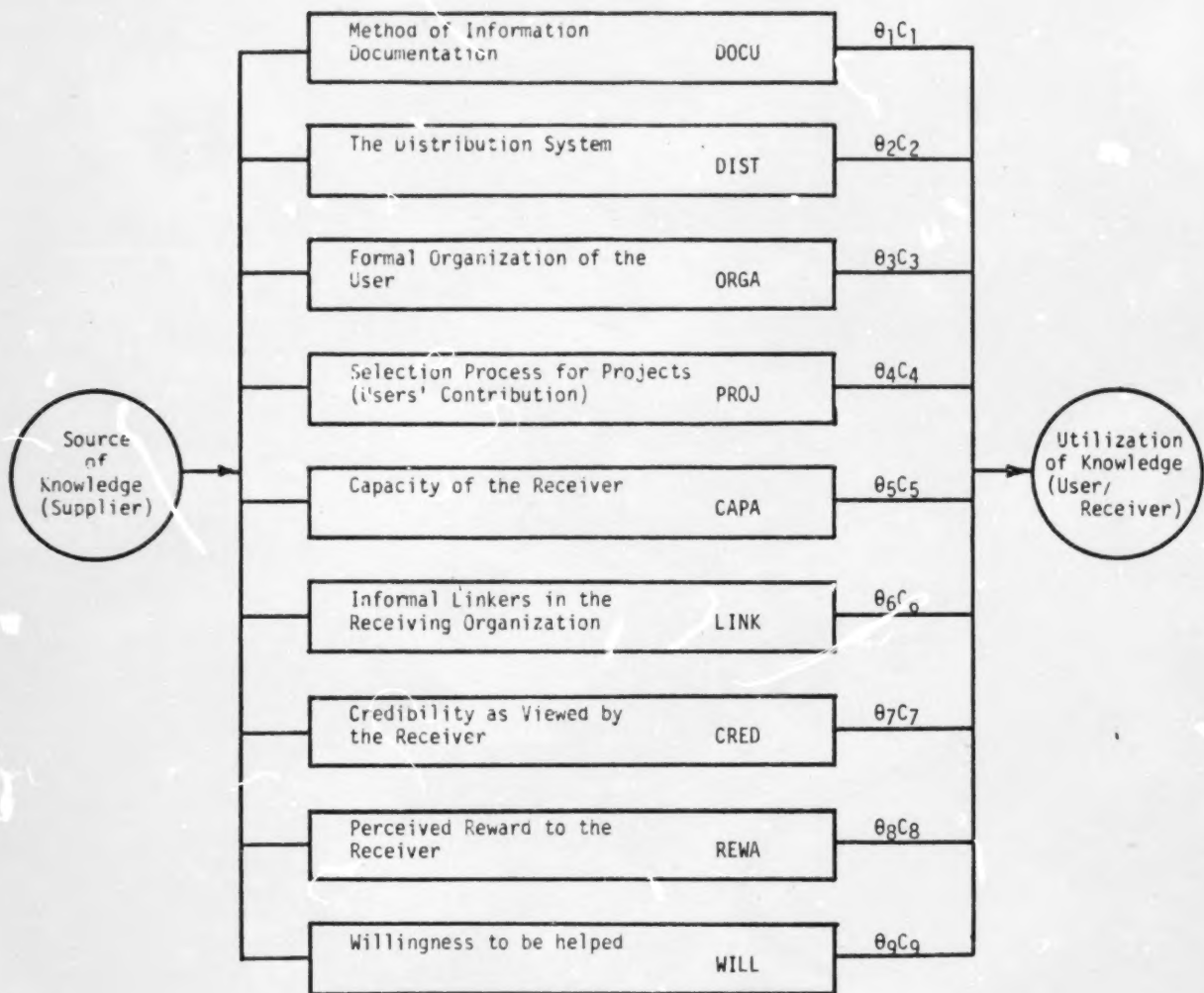
To make the brief descriptions of each factor in the model clearer, each factor is discussed.

DOCUMENTATION (DOCU):

This is the format, organization, or presentation of the technology being transferred. Format and language relate directly to the understanding of the material by the receiver. One cannot utilize information that one cannot interpret.

Knox (1973, p. 415), Director of the National Technical Information Service, has said that:

"The maximum amount of time a scientist or engineer devoted to interaction with the information system in science and technology has not changed in the last 25 years. Studies since 1948 have shown that scientists and engineers spend 3 to 4 hours a day at most, on reading journals, talking with peers seeking information, and similar activities. . . They allocate as much time to interaction with information systems as they feel profitable and



The model may be expressed in equation form such that:

$$L_i = \sum \theta_j C_k$$

Where

L_i = Linker index for an organization i

θ_j = A measure of factor utilization, θ_j range $0 \rightarrow 1$

C_k = A measure of the factor contribution, $\sum C_k = 1$

Figure 2 Predictive Model of Technology Transfer

The linking mechanism necessary to achieve effective technology transfer is described by identifying the factors that contribute to movement of technology from the source of knowledge (supplier) to the utilization of knowledge (user/receiver).

productive. . . New users (for example, state, and local governments and citizens groups) want to spend much less time getting answers to their questions. . ."

Organizations seriously interested in improving the effectiveness of their documentation effort have adopted techniques based on good marketing principles. For example, the Navy's Civil Engineering Laboratory at Port Hueneme, California, has a procedure whereby several levels of users are considered. In addition to the end of a project report, a series of "Rap Briefs" and a series of "Tech Notes" are also issued to improve the utilization of the information. This type of effort can improve technology transfer by adjusting the documentation to meet the needs of the user.

DISTRIBUTION (DIST):

This is the physical channel through which technology flows and involves both the number of entries and ease of access into the channel as well as the formal distribution plan.

Knox (1973, p. 416), stated, "A primary measure of the effectiveness of the technology information system is its capacity to allow people with problems to get in touch with people (or records) with potential solutions."

Ames (1965, p. 84) studied the behavior of 3,021 scientists and engineers in the United Kingdom to determine their information needs. He found that abstracts and original papers were considered the most important source of specific information. Reviews, meetings, and conferences

were the best vehicle for current awareness. Perhaps meetings and conferences are not considered as information distribution vehicles. However, when the proposition that the distribution of new and/or innovative technology is effective only when awareness exists, it becomes more acceptable to include the interpersonal exchange that occurs at meetings and conferences as part of the technology transfer distribution system. In his findings Ames (1965), p. 88) also found that 28% of the scientists studied had encountered delays in their research owing to their ignorance of previous or current research. This certainly emphasizes the importance of a knowledge distribution system and further supports the inclusion of the factor DISTRIBUTION in the technology transfer model.

ORGANIZATION (ORGA):

This is the receivers perception of the formal organization. Schon (1967, p. 211) describes the attitude of many formal organizations to technology change as:

The. . ."theory of the stable state, as applied to organizations, is the enemy of adoptive change. In fact, in most organizations the structure of power, the nature of the business, the organization of work. are all in the process of continual change. . . but there is a taboo against the acceptance of this change. The representative of a new order, in the organization, feels obligated to present himself as, for all practical purposes, permanent, and to behave as though the changes he is introducing will be the last. . ."

Furthermore, Schon (1967, p. 134) characterized an organization that is favorable to technology transfer and utilization of knowledge as living in a state of pressure to perform where conflict is resolved by fiat, where resources

are committed without hesitation, and where uncertainty is converted to risk.

Thus a formal organization may have bureaucratic tendencies that tend to obstruct change simply because a comfortable environment is one of equilibrium. The determination of an attitude to accept or reject change by a formal organization can produce an insight into that organization's expected utilization of new and/or innovative ideas.

Stephenson, Ganz and Erickson (1974, p. 22) reported the responses of 109 scientists and engineers from the Naval Weapons Center, China Lake, California, in terms of their perceptions of management creating conflicting forces. Forty respondents felt that an organization occasionally or often acted as a barrier to the use of new ideas.

PROJECT (PROJ):

This factor refers to the selection process for research and development projects undertaken by the source, and the receiver's contribution to that process. Two authors have shown that "a basic reason for the lack of research utilization is that the process is often begun with the research process, rather than the client's needs," (Rogers and Jain, 1969, p. 9).

Another problem in selecting projects was reported by Stephenson et al (1974, p. 220). They showed that 29% of 109 scientists and engineers studied felt that the men making the decisions "upstairs", although able administratively, were not current technically and frustrated new ideas from below.

CAPACITY (CAPA):

The capacity of the user to utilize new and/or innovative ideas covers a wide spectrum of traits including venturesomeness, wealth, power, education, experience, age, selfconfidence, and cosmopolitaness.

Pelz and Andrews (1966, p. 259), studied 526 scientists and engineers in five industrial laboratories and 641 research personnel in five government laboratories. Their studies demonstrated the importance of the capacity trait as related to personal performance. "In short: Effective older groups (groups with higher education) were those which maintained the energy of young groups (interaction and competition), but replaced an atmosphere of friendly warmth with one of intellectual rivalry -- sometimes toward each other, and often toward outsiders."

Loy (1969, p. 77) extended the work of Rogers by investigating the prediction of innovativeness. One hundred and six respondents completed a questionnaire and interview covering seventeen socio-psychological attributes. Six attributes (venturesomeness, professional status, imaginativeness, educational status, dominance, sociability, and cosmopolitaness) were significant at the 0.01 level (F test). A seventh attribute, self-sufficiency, was significant at the 0.05 level.

The attributes that did not appear to be important were perseverance, peer status, intelligence, occupational status, social status, shrewdness, experimentiveness, surgency and sensitivity.

LINKER (LINK):

This refers to the presence of and effects of informal linkers in the receiving organization. This concept assumes that the linker operates within the organization which receives the knowledge. This restriction on the role of the linker decreases the usual typology of linking roles to that of the leader (gate keeper and opinion leader), early adopter of an innovation (innovator), and early knower of an innovation. Therefore, the user's linking role is defined as: "To link by taking initiative on one's own behalf to seek out scientific knowledge and derive useful learning therefrom," (Havelock, 1971, pp. 7-4a).

The concept that the linker operates as a coupling device between the source and user of knowledge within the user organization rejects the general definition that the linker's role is, ". . . simply the gathering, processing, and distribution of . . . knowledge," (Farr, 1969, pp. 3-4). The Farr definition assumes that the linker is solely an intermediary acting as the interface between knowledge and need. Such an assumption does not recognize the fact that the coupling or linking mechanism within the user's organization is only part of a larger process of technology innovation within that organization.

The linker concept as applied here is that a linker functioning within the user's organization would exhibit identifying traits and characteristics similar to the gate keeper, opinion leader, innovator, and early knower of an innovation.

CREDIBILITY (CRED):

Credibility is an assessment of the reliability of the information as perceived by the receiver. It is evaluated by analyzing both the source and channel of the message because it is often difficult for the individual to distinguish between the source of the message and the channel which carries that message. Thus the individual attaches a composite credibility to the message derived from both perceived source and perceived channel.

The concept of credibility as a factor is based on cognitive dissonance theory (Festinger, 1962). The importance of credibility as a factor in the linking mechanism is shown by Aronson et al (1963, p. 3) in which a laboratory experiment showed unequivocally that opinion change is a function of the credibility of the source.

Holland (1972, p. 30) also studied the information-source value placed on an individual by his colleagues in three organizations. His work strongly supports the concept that the credibility of information will be influenced by its source and its channel.

REWARD (REWA):

Reward is the perceived and actual recognition of innovative behavior in the social system of which the individual

is a member.¹ The concept and importance of the reward system to the scientist and engineer is summarized by Pelz and Andrews (1966, p. 139):

"The implication is that the research director (or manager) must give close attention to the whole system of rewards -- both intrinsic and extrinsic. He must live with the paradox that extrinsic rewards cannot be relied on to motivate achievement, but that when achievement occurs, the extrinsic rewards should be consistent."

WILLINGNESS (WILL):

Willingness relates to the individual's ability and/or desire to accept change in the organization of which one is a member. The adoption rate of ideas was studied by Gallup. Some of his findings are quite appropriate to the problem of technology transfer. For example, Gallup (1955, p. 232) pointed out that although an idea has been accepted intellectually, normally a long period of time passes before it is incorporated into the thinking of the person who has accepted it.

Gallup (1955, p. 233) stated that, "Persons with vested interests, if there be any, will see to it that mental road blocks are put in front of every new idea which deprives

¹"...Reward achievement falls into two broad categories: Rewards intrinsic to the work itself (such as opportunity to use skills, to gain new knowledge, to deal with challenging problems and to have freedom to follow up one's own ideas) and those extrinsic to the technical content (a good salary, higher administrative authority, association with top executives)." (Pelz and Andrews, 1966, p. 139).

them of prestige or power."

The concept that you can lead a horse to water, but that you cannot make him drink certainly applies to the case of new and/or innovative ideas. Awareness, even first hand knowledge of a new and/or innovative idea is not sufficient to assure its use. There must be a willingness and interest or perhaps even more significantly an internal motivation to utilize a better method, process or concept.

Spencer of Howard University stated (Gilmore 1969, p. 20) that, "Something more is necessary for technology transfer to be effective, that something more is the personal element. . . ." Wright (1966, p. 35) expresses the same thought, "It is demonstrably evident that a critical point in the transfer and utilization mechanism is frequently the personal confrontation of the intended user with the innovator."

Referring back to the model (see Figure 2) which includes the factors just described, several mathematical symbols are shown which are used to construct an equation called the Linker Index. It is hypothesized that the Linker Index represents the effectiveness of an organization's ability to achieve technology transfer.

The mathematical symbols represent the following:

- θ_j This coefficient is a measure of the utilization of the factor to which it is applied for each organization or individual. Its value may range from 0 to 1.
- C_k This coefficient is a measure of the contribution of each factor to the total transfer process. The sum of all C_k factors equals 1. C_k may vary according to the population sector being studied.

By multiplying the θ and C coefficients for each factor and summing for each organization, a numerical value may be determined and may be used in predicting the degree of technology transfer within each user organization.

Transfer Mechanism -- Formal Communications vs. Informal Communications Factors

Documentation, search facilities, and distribution channels are significant elements in the methodology model that considers and describes the process of the flow of technical information from the source to the user. Formal communications may be identified as separate factors from the informal factors. The informal factors are behavioral and/or sociological in nature and tend to contribute heavily to the success of the utilization of knowledge by an organization. Figure 3a conceptualizes the fact that the knowledge flow enhancement factors may be logically divided into two categories. Figure 3b then better defines each of the categories and further clarifies the definition of formal versus informal.

Using this as a basis for grouping the factors, the original model of technology transfer as shown in Figure 2 may be divided to reflect the importance of the formal versus the informal communications components of the transfer mechanism (see Figure 4).

A small number of studies have examined the extent of the use of formal versus informal knowledge flow enhancement factors. Four such studies, Glock and Menzel (1958) of 77 scientists,

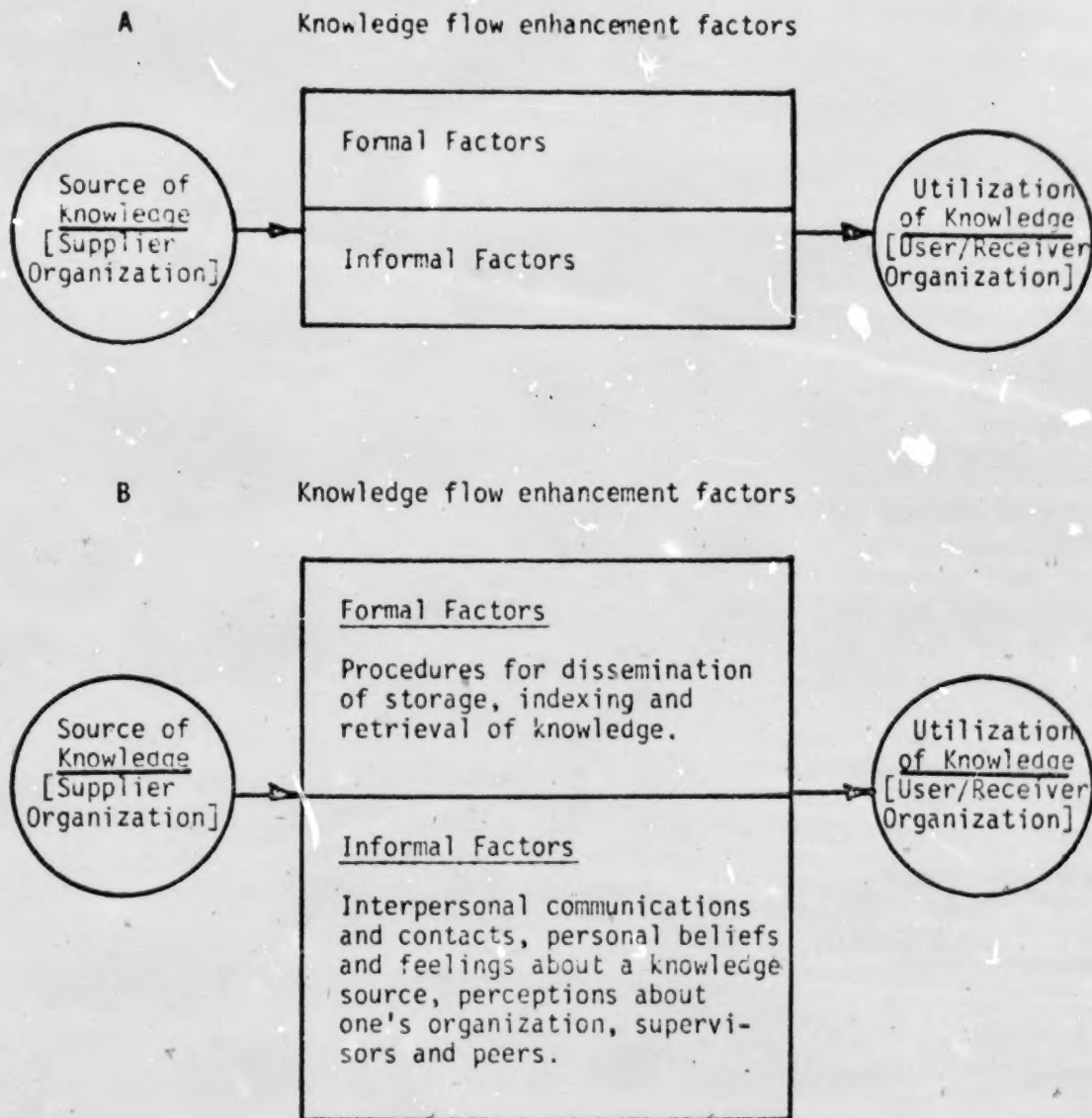
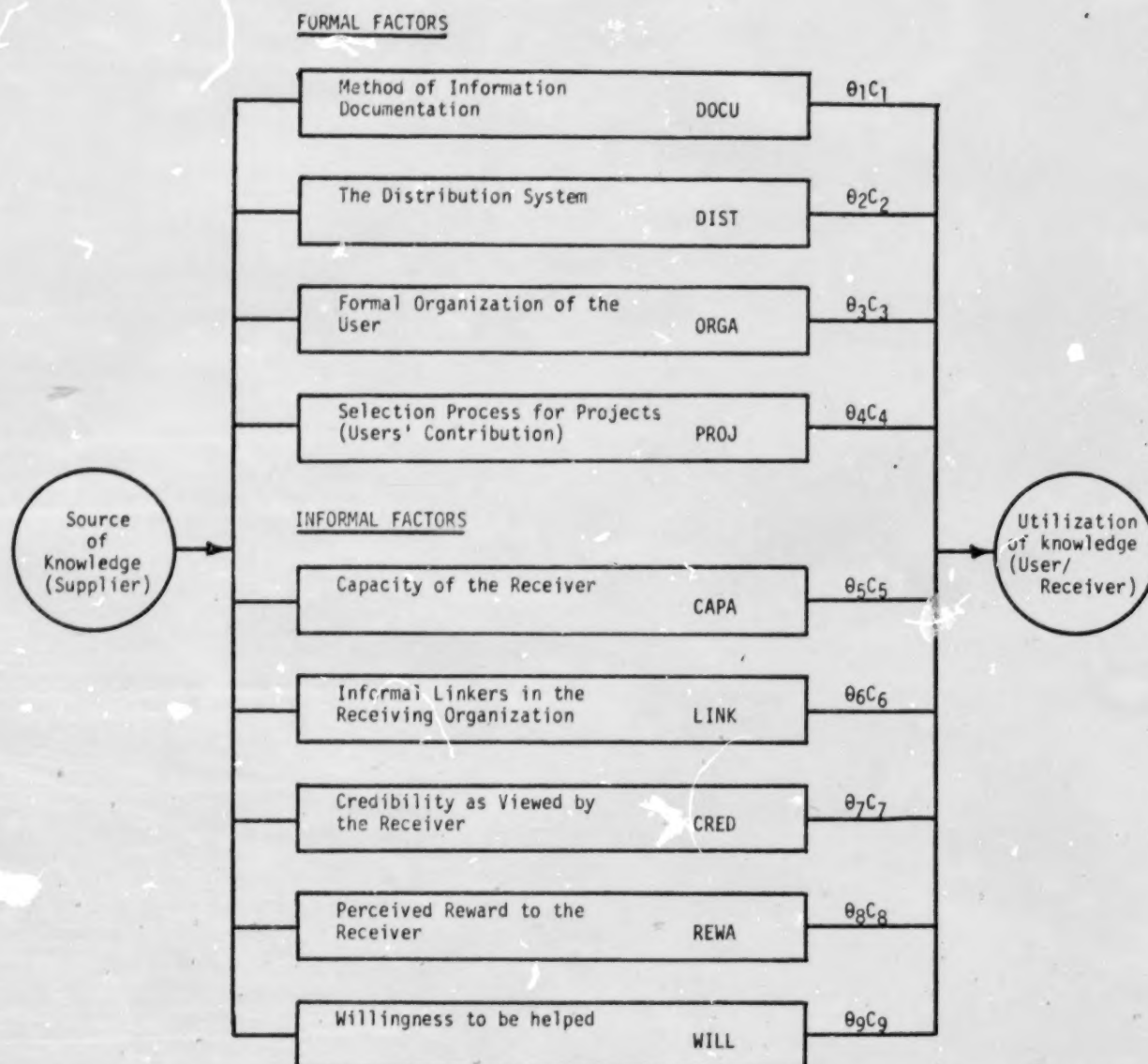


Figure 3. A Simplified Model of Technology Transfer

- a. The movement of knowledge from the source to the user/receiver may be classified according to formal factors and informal factors.
- b. The formal and informal factors are defined. The formal factors are procedural in nature, and the informal factors are behavioral.



The model may be expressed in equation form such that:

$$L_i = \sum \theta_j C_j + \dots + \theta_k C_k$$

Where

L_i = Linker index for an organization i

θ_j = A measure of factor utilization, θ_j range $0 \rightarrow 1$

C_k = A measure of the factor contribution, $\sum C_k = 1$

Figure 4 An Expansion of the Predictive Model of Technology Transfer

The factors in the predictive model have been grouped according to the classifications formal factors and informal factors. The factors classified formal are procedural in nature and the factors classified informal are interpersonal and/or behavioral.

Auerbach (1965) of 1375 scientists, Rosenbloom and Wolek (1967) of 3200 scientists and engineers, and Graham et al (1967) of 326 managers of research and development projects agreed closely that the communications channel usage was divided, informal 55% and formal 45%.

The arrangement of the model as shown in Figure 4 makes it possible to assign partial values to C_k .

Formal factors

$$C_{\text{formal}} = C_1 + C_2 + C_3 + C_4 = 0.45$$

Informal factors

$$C_{\text{informal}} = C_5 + C_6 + C_7 + C_8 + C_9 = 0.55$$

and

$$C_f + C_i = 1.0$$

This model does supply a logical framework for further research. With additional research values may be developed for each of the coefficients.

Implications of the Model

With additional research definitive weights for the coefficients of the factors in the model may be developed and instruments to measure the performance of an organization in terms of each factor area may be developed, tested and verified. Through these efforts a method of quantification of the effectiveness of an organization in terms of its ability to transfer technical information can be developed.

The justification for such continued efforts to quantify the ability of an organization to transfer technology must be based on the economic value to the organization and/or to society as a whole.

As with many studies of an organization, the mere act of attempting to quantify as well as conceptualize models may develop a level of awareness that in itself may substantially contribute to the enhancement of the technology transfer process. For example, one of the important benefits of systems analysis is the careful delineation of the problem and the methodical listing of the alternative solutions.

At this point in time, little is known about the characteristics of organizations in terms of their ability to capitalize on the process of technology transfer. Is there a significant difference between public sector organizations and the private sector organizations? Perhaps more important, is there a large range of performance within either of these two sectors?

It can be hypothesized that many of the factors in the predictive model of technology transfer could conceivably be improved for a specific organization, if upon examination it was determined that a deficiency existed. Some of the factors have tangible and even measurable performance standards at the present time. It would seem that the formal communications factors should be quite easy to rate as to their degree of effectiveness in aiding the technology transfer process. If

this is true, it should be possible to extend the argument and suggest that, for the formal factors, once a performance level was established, significant steps could be made that would enhance the effectiveness of the technology transfer process.

. The informal factors are less subject to improvement through structural change. However, concentrated interest and efforts should cause significant change in the informal factors area. Education and training can be effective in changing a persons attitude and feelings about the relative importance and usefulness of the technology transfer process.

In summary, the predictive model of technology transfer is useful in terms of awareness. In addition the model has a future usefulness in terms of providing a basis for a quantitative measure of the effectiveness of an organization to capitalize on the technology transfer process. A quantitative index of the effectiveness of an organization to utilize technology transfer could provide a standard for comparison and improvement measurement.

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